Bridge

Questions

(Q1) Define the term bridge and list out the form of bridge structure. (5 marks)

(Q2) List out the advantage of bridge. Describe briefly the component of bridge structure with neat sketch (2+8)

(Q3) List out the selection factor for ideal bridge site (5 mark

Q4) Describe brief factor affecting superstructure of bridge. Define the term economic span of bridge (3+2)

Q5) Describe the types of bridge (10 marks)

Q6) List out load, force, stresses acting on bridge structure as per IRC (10 marks)

Q7) Classify the bridge as per NS. (3 marks)

Q8) Listout the design consideration method of bridge (

Q9) Describe load distribution mechanism for bridge st

Q10) Write down the design steps for box culvert, T-beam der bridge.

Q11) Describe Corboun method of bridge.

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(Q) Define the term bridge and briefly describe the form of bridge structure? (5 marks).

⇒ Definition:

→ It is a structure providing passage over an obstacle without closing the way beneath.

→ It is provided in railway, highway and footway over intersection of roads, river, stream, lake etc for smooth crossing of vehicle, people, train and utility services.

* Forms of bridge structure are as follows:- (ABC CST)

i) Beam bridge
ii) Truss bridge
iii) Arch bridge
iv) Cantilever bridge
v) Suspension bridge
vi) Cable-stayed bridge

i) Beam bridge

→ Carry vertical load by flexure.

ii) Truss bridge

→ behaves like a beam since it carry vertical load by bending where top chord and bottom chord experiences compression and tension force.

→ vertical and diagonal member are subjected to compression or tension force as per orientation.

iii) Arch bridge

→ Load are carried primarily in compression and reaction at support get converted to horizontal and vertical force..

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iv) Cantilever bridge

→ Carry tension force in upper chord and compression in lower chord.

vi) ~~Suspension bridge~~ Cable-stayed bridge

→ ~~Carry vertical load on deck are carried by nearly straight inclined cables which are in tension.~~

→ Tower transfer the cable force to foundation through vertical compressive force.

→ ~~Further load are transferred to ground through tower and anchorage.~~

vi) Cable-stayed bridge

→ ~~vertical load on deck are carried by~~

→ The tensile force in stayed cable induce horizontal compression in deck.

→ ~~Carry~~ vertical load on deck are carried by nearly straight inclined cables which are in tension.

v) Suspension bridge

→ Carry vertical load from the deck through curved cable in tension. These loads are transfered to the ground through tower and anchorage.

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V. Imp

Selection of bridge site:-

(8) list out the characteristics of an ideal bridge site, (5 marks)

=> Choice of the right site is a crucial decision in the planning and designing of a bridge. It may not be possible always to have wider choice of bridges.

The characteristics of ideal bridge site are as follows:-

i) A straight reach of river,
ii) Steady river flow withouth whirls and cross currents.
iii) A narrow channel with firm banks.
iv) Suitable high bank above high flood level on each side.
v) Rock or other hard strata (inerrodible) close to river bed level.
vi) Proximity to direct alignment of road to be connected.
vii) Absence of sharp curves in approaches.
viii) Absence of expensive river training works.
ix) Avoidance of excessive underwater construction.
x) No scouring and silting of stream at bridge site.

Note:-

i) For major bridge to select suitable site, investigating engineer should do a recci survey for about 1 km in upstream and downstream site.

ii) When the river is to be crossed in meandering river, the bridge should be located at nodal point (the point where river regime is constant serving as a fulcrum about which river channel swings laterally.

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iii) Bridge should be aligned to right angles to the river i.e. to prove square crossing which facilitates minimum span length, deck area and pier length.
(Square crossing involves simple design and detailing)

Extra points

i) It should be geologically sound area having less amount of fault.
ii) Should be accessible to approach road.
iii) Foundation should be stable.
iv) Cost should be minimum and economical as possible.
v) Required skilled manpower.

* ~~Economical Span:~~

(a) List out the governing factors in selection of bridge superstructure. (5 marks) List out the types of bridge as governed by IRC based on technical and economic factors (5 marks).

⇒ The governing factors in selection of bridge superstructure are as follows:-

A) Technical factor
- → Span coverage of bridge superstructure
- → Horizontal and vertical clearance of bridge
- → Soil condition (subsoil)
- → Durability
- → Time and method of construction.

B) Environmental factor.
- → Impact of structure on environment during and after construction.

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→ Impact on marine life, surrounding human life and plant life.

C) Economic factor

→ Related to cost factor i.e. availability of fund and financial aspect for construction.

→ Cost factor include
- Cost of labour, material and maintenance cost
- No. of span length, pier ht.
- Transportation cost and erection cost.
- Time and design load availability consideration.

D) Aesthetic factor

→ Represent quality of beauty and functionality of bridge structure.

→ Factor include
- Appearance, colour
- Contrast, proportion
- Scale, order
- Environmental integration
- Functionality.

The types of bridge as per IRC based on technical and economical factor are:-

S.N	Types of bridge	Span (m)
1)	RC. slab	(6-10)
2)	RC. T-girder beam	(10-30)
3)	Masonary bridge	(15-30)
4)	Composite	(25-40)
5)	Truss type bridge	(25-300)

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6) R.C box bridge (30-50)

7) Prestressed concrete box bridge (40-80)

8) Cable stayed bridge (100-200)

9) Suspension bridge (200-2000)

(Q) (VIMP) Define the term economical span of bridge? (2 marks)

⇒ Definition:-

⇒ Total cost of bridge which will be minimum for a span is termed as economical span of bridge.

⇒ Total cost of bridge = (total cost)$_{\text{super structure}}$ + (total cost)$_{\text{sub structure}}$

Expression for economical span of bridge:-

⇒ Assume the ratio of cost of one span (S) to the cost of one pier (P) be R i.e.

$$R = \frac{S}{P} \qquad \therefore S = R \times P.$$

we have,

total cost of bridge it is given as,

$$C = nS + (n+1) \times P$$

C → total cost of bridge, n → no. of span, S → span, P → pier

$$n = \frac{L}{l} \quad \text{--- (1)}$$

$$\frac{L}{l} - 1 - 1$$

$$\frac{L}{l} - 2$$

$$\therefore \left(\frac{L}{l} - 1\right) P$$

$$\frac{L}{l} P - RP + \frac{L}{l} P - 1P$$

$$\frac{dC}{dl} = -\frac{L}{l^2} RP - \frac{L}{l^2} P = 0$$

$$-\frac{L}{l^2} RP = \frac{L}{l^2} P$$

$$L(RP+P) = 0$$

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For maximum or minimum,

$$\frac{dc}{dn} = 0$$

$C = ns + (n-1) \times R$

Put $S = RP$

$C = n(RP) + (n-1) \times P$

Now,

$$\frac{d}{dn}\{n(RP) + (n-1)P\} = 0$$

or, $PR + (1) \times P = 0$

or, $PR = -P$

$\therefore R = -1 = 1$ (-ve neglect)

$\therefore$ Economical span is one for which the cost of one span equal to pier.

$\therefore$ Economic span = (Total cost) superstructure = (Total cost) substructure

Imp

(Q) List out the importance of bridge. Explain with neat sketch the component of bridge. (10 marks).

=> Importance of bridge:

i) It add beauty to cities.

ii) It improves social, cultural and economic condition.

iii) provide a quicker, easier way to travel from A to B.

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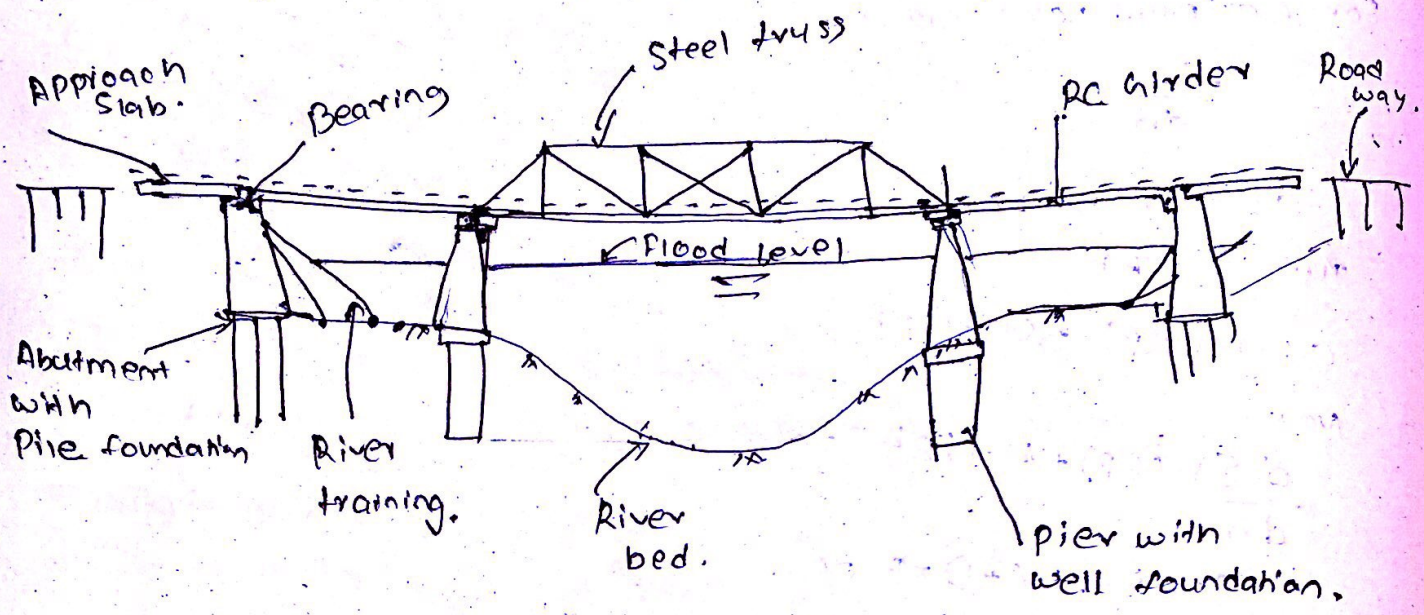

Fig:- Components of bridge.

Components of bridge

A) Superstructure:-

- Above level of bearing
- Provide base for moving vehicles, trains and pedestrains.
- wearing surface is a portion of deck which resist traffic wear.
- Wearing surface is a separate layer made of bituminous material.
- Deck is the physical extension of roadway across the obstruction to be bridged. It is made of RCC slab.
- Primary member like beam, truss, Arch, frame distribute bridge load longitudinally.
- Secondary member like bracing are used to connect primary member which transfer load transversely.

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B) Bearing

-> Mechanical device placed between superstructure and sub structure to transmit vertical and horizontal load to substructure.

-> It allows translation and rotation moment.

C) Substructure

-> Structure below the bearing level are substructure

-> Provides support for superstructure and transfers load from superstructure to soil.

-> Consist of abutment, pier and foundation.

* Abutment:

-> End support of bridge which retain earth surface and provide support for superstructure.

Pier:

-> Intermediate support of bridge which provide support for superstructure.

Footing / Foundation:

-> Structure which support piers and abutment and transfer load from pier to abutment and to subsoil.

D) Appurtenances and site related structure:-

-> Non structural element which serve in the overall functionality of the structure.

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Embankment and slope protection work:-

→ Provide proper drainage, control erosion, and increase beauty of bridge.

Approach slab:-

→ Provide smooth transition of load from flexible road surface to rigid bridge surface.

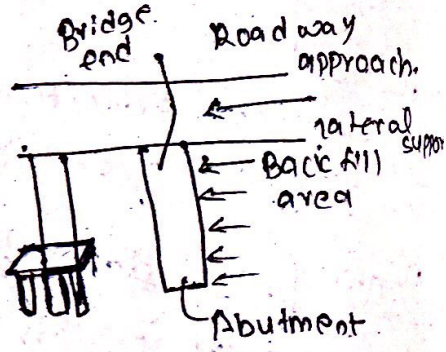
River training structure

→ structure which guides and regulate river course in desired direction and protect bridge substructure.

Extra note:- (2 marks):

i) Abutment:-

→ End vertical support of bridge for superstructure or deck,
→ Act as roadway approach,
→ Retain roadway backfill,
→ Resist lateral movement of earth fill,
→ Act as vertical and lateral support.



ii) Wing wall:-

→ Located near abutment,
→ Extension of abutment
→ found in right angled and splayed form,

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iii) Support of bridge

-> Two types of support in bridge

(1) End support : along the abutment

(2) Intermediate support or pier support :- Pier are supported by pier cap to ~~bear~~ resist sufficient bearing capacity.

iv) Bearing pad :-

-> It is known as elastomeric bearing pad.

-> It absorbs compressive force, control effect of shock and vibration.

-> It distribute superstructure load to substructure and allow superstructure to undergo movement without creating any harmful stress.

-> Elastomeric bearing pad are used to control wear and tear action below superstructure and substructure.

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(6). Describe the types of bridge along with positive and negative aspect? (10 marks)

=> The bridge are boardly classified into various categories:-

A) According to means of transport

i) Highway bridge
ii) Railway bridge
iii) Pedestrain bridge
iv) Utility bridge.

B) According to material used in ~~stru~~ superstructure

↳ timber bridge
↳ masonary bridge
↳ Rcc bridge
↳ steel bridge (2 marks)
↳ Pvestressed concrete (2 marks)

Imp (5 marks) (major types of bridge) → crosssection figure.

C) According to types of superstructure

i) Slab bridge
ii) T-beam bridge
iii) Box-girder bridge
iv) Truss bridge
v) Arch bridge
vi) Frame bridge
vii) Suspension bridge
viii) Cable stayed bridge

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i) Slab bridge

Fig:- Solid slab bridge.

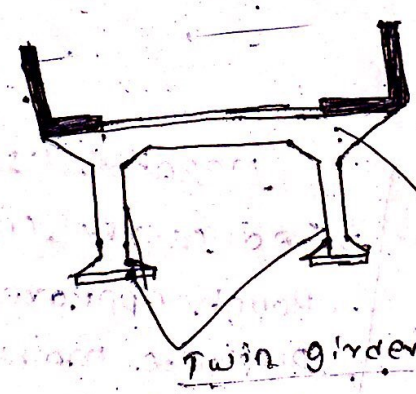
positive aspect

- → Increase clearance above afflux due to depth being shallower.
- → Good appearance
- → Better lateral load distribution characteristics due to torsional stiffness being better.
- → Less maintenance cost.

Negative aspect

- → self wt. is heavier
- → Less span applicable i.e. < 15 m
- → It is economically not effective for large span.

ii) T-beam bridge



Twin girder bridge deck

fig:- T-beam.

positive aspect

- → Easy to construct since it compromise simpler geometry.
- → monolithically casted so given economical design.

negative aspect

- → Less better appearance.
- → It is effective economicall upto 30 m span of bridge.

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iii) Box - girder bridge :-

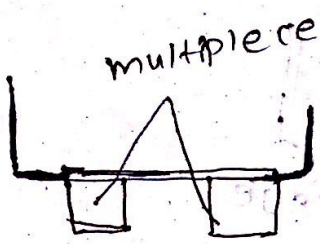

Fig :- Box - girder bridge (multiple cell).

Positive aspect:

1 -> Decrease cost of construction for longer span bridge.
-> Better appearance
-> Good lateral load distribution characteristics and suitable for curved bridge
-> Economic for span greater than 30m.

Negative aspect:

-> Casting ~~in situ~~ in situ is complex
-> Requires high skilled manpower and advanced machineries.

iv) Truss Bridge

Positive aspect

-> Rigid structure, Easy for construction, useful for large span bridge.

Negative aspect

-> Reduce vertical clearance
-> Rough appearance
-> Periodic maintenance. (regular)

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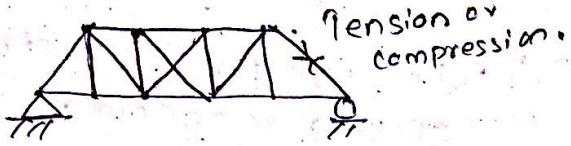
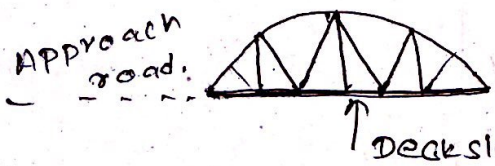


Fig:- Truss system.

v) Arch bridge :-



→ Main load resisting member arch which follow parabolic nature

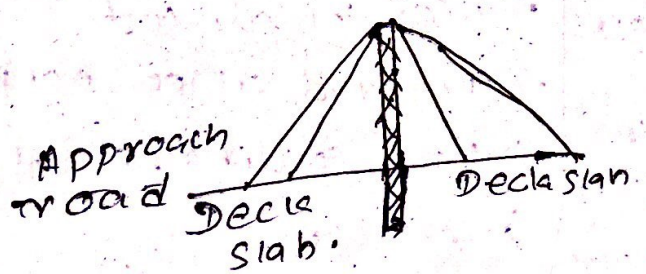
Positive aspect:

→ Good appearance
→ Gives economical structure section
→ Span upto 150m for steel Arch bridge
→ Horizontal thrust reduce B.M in arch.

Negative aspect:

→ Require good soil properties for foundation.
→ High fabrication and erection cost
→ Different construction way.

vi) Cable stayed bridge



→ Main ~~tower~~ load is taken by tower and cable. (resistance).

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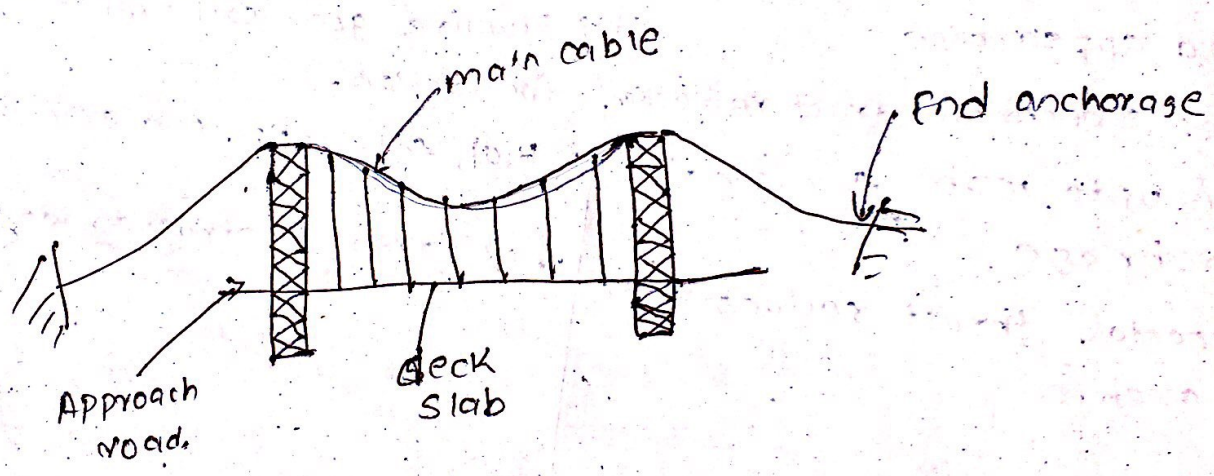
Positive aspect

- No. of pier, bearing, foundation reduced.
- Resist tension since cable carry tension.
- Tower finally transmit compressive force to foundation.
- Used for longer span, mainly to avoid under water construction.

Negative aspect

- Require regular monitoring, Stilled manpower.
- Economically only for long span.

vii) Suspension bridge



- Load resisted mainly by cable system.

positive aspect

- No. of bearing, pier foundation are reduced.
- Design based on maximum tension for cable
- Economic for large span (>1km)
- Load distribution is better.

Negative aspect

- High initial cost
- Required skilled manpower.
- Good condition of subsoil for anchorage.

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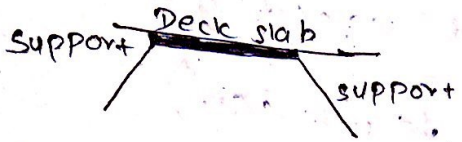
viii) ~~Cabressed~~ Frame bridge:-



Positive aspect

→ Good appearance, no need expensive bearing, stable structure

→ upto 100m span.

negative aspect

→ Good subsoil properties.

D) According to support condition of super structure:-

⇒ i) Simply supported bridge
ii) Cantilever bridge
iii) Continuous bridge
iv) Rigid frame bridge

E) According to type of service

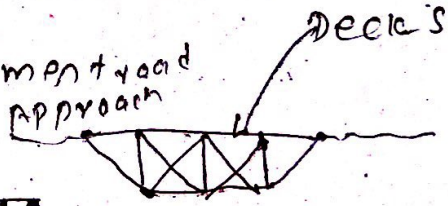
⇒ (1) Permanent bridge
(ii) temporary bridge.

F) According to ~~the~~ profile of bridge:-

⇒ (1) Straight bridge
(2) Curved bridge
(3) Skewed bridge

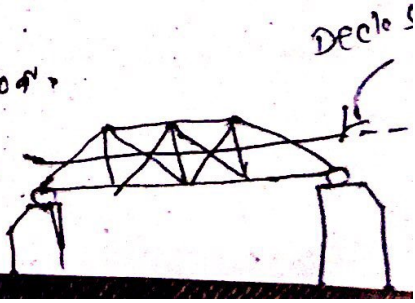
G) According to floor arrangement ⇒

i) Deck



2) Through ⇒

3) Semi-through (Half bridge



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Imp
H) According to Nepal standard 2067, bridge is classified according to span length. (5 marks)

span → c/c distance between pier.
length → Total length of bridge

→ (1) Culvert (span length ≤ 6m)

(2) Minor bridge (length ≤ 50m) (span ≤ 25 m)

(3) major bridge (length > 50m) (span > 25 m)

(4) Special bridge (

→ Required special design consideration

for eg:→ Concrete girder bridge,

→ Steel truss bridge,

→ Arch bridge,

→ Suspension bridge,

→ Cable stayed bridge

* Free board → minimum F.B of not less than 1m is applied as per NS.

* Discharge (m^3/sec)	Min^m free board (as per NS)
less than 200	1 m
201-500	1.2 m
501-2000	1.5 m
2000-5000	2.0 m

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* Vertical clearance:- (NS)

(1) For all road not less than 4.75 m through structure

(2) over head, wire, pole at least 7m above highest point of road surface.

* Carriage way width:- (NS)

=> i) for highway and urban road minimum carriage way width 7.5m

ii) for feeder road, minimum carriage way width = 6m. not less than.

iii) Permanent bridge => minimum carriage way width 6m.

IMP

* Types of steel bridge (2 marks)

=> Steel bridge is classified on the basis of traffic carried and structural system.

A) Traffic carried

i) Highway bridge.

ii) Railway bridge

iii) Road cum Railway bridge

B) Classification based on structural system:-

i) Suspension bridge (550-2000 m) span.

ii) Cable stayed bridge (150-700 m)

iii) Arch bridge (150-500 m)

iv) Truss girder bridge (30-550 m)

v) Box girder bridge (upto 250 m)

vi) Cantilever bridge (300-500 m)

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⑨ Load classification

① 2078 PSE

List out and discuss the load, force and stress which are to be considered in the design of road bridge. (10 marks)

② Describe the types of live load on bridge (5 marks)

③ Describe the impact and lateral load on bride. (5 marks)

=> The different types of loads, force, stress acting on road bridge are as follows:-

1) Dead load,
2) Live load,
3) Impact load,
4) wind load,
5) Longitudinal force,
6) centrifugal force,
7) Buoyancy effect
8) water pressure
9) Thermal effect,
10) Seismic force
11) Earth pressure
12) Deformation stress,

1) Dead load:

-> Self wt of bridge element;
-> Dead load are Deck slab, wearing coat, railing, parapet etc.
-> Material ~~dead load~~ weight (t/m³)

Brick work in cement mortar	1.9
Earth compacted	2.0
steel	7.8

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2) Live load (u.Imp)

-> moving load on bridge throughout
-> Example :- Pedestrain, traffic load (vehicle
-> Difficult to select one vehicle or group of vehicle
-> So, IRC recommend some value of vehicle.
-> vehicle load are classified in four category :-
  a) IRC class AA loading -> Ground contact length : 3.6m
  b) IRC "A " "
  c) IRC "B "
  d) IRC class 70R "

Class AA loading

-> Heavy military vehicle
-> checked for class A loading
-> Types of vehicles

a) Tracked vehicle
Packed load : 70t (equally distributed over two track of 0.8m width). 0.6m
-> length of vehicle => 7.2m
-> out distance => 2.9m b/w track

b) Wheeled vehicle
-> Maximum load for single axle => 20t
-> maximum wheel load => 6.25 t
-> Nose to tail spacing between 2 vehicle 4.90m

Class A loading

-> Heavy commercial vehicle
-> permanent road bridge and culvert
-> standard live load of bridge (consideration)

Types of
a) Footway
-> Accessible only to pedestrains and animal having live load 4kN/m²
-> At crowded places or pilgrimage => L.L of 5kN/m²

b) Successive trains
-> Min^m distance between successive trains = 18.4m.

Class B loading

-> Design of temporary structure.
-> considered as light loading.

Class 70R loading.

-> can be used in place of AA loading
-> 'R' denote revised classification.

Types of vehicle

a) Tracked vehicle
-> similar to class AA loading
-> Ground contact length = 4.75m
-> Length of vehicle => 7.92m.
-> Min^m spacing between successive vehicle => 30m.

b) Wheeled vehicle
-> Length of vehicle = 15.2
-> contain 7 axles with total load of 100 t
-> Additional 40 t o bogie loading.

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3) Impacted load

→ Caused by vehicle moving on bridge: (sudden load)

→ Impact factor is considered.

→ Impact factor depend upon speed of vehicle, span of bridge, weight of vehicle.

→ Impact factor $\propto \frac{\text{speed of vehicle}}{\text{Span of bridge}}$

→ Footway not consider for impact load.

For class 'A' and 'B' loading

Bridge span	RC bridge	steel bridge
Less than 3m	0.5	0.545
3m - 45m	$\frac{4.5}{6+L}$	$\frac{9}{13.5+L}$
more than 45m	0.088	0.154

For class AA and class 70R loading

Bridge span		Tracked vehicle	wheeled vehicle
Less than 9m	up to 5m	0.25	0.25
	(5-9)m	0.1	
more than 9m	RCC bridge	up to 40m => 0.1	up to 12m = 0.25
	Steel bridge	0.1	up to 23m = 0.25

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(4) Wind load

→ Negligible for short span.
→ Medium bridge, exist for substructure design.
→ Long bridge, exist for superstructure design.
→ Load (P) α square of velocity (v^2)
→ wind load act at height 1.5 m from roadway.

5) Longitudinal load

→ Caused by sudden braking or accelerating of vehicle on bridge
→ Act mostly on substructure.
→ IRC recommends 20 % of LL to be considered as longitudinal force on bridge.

6) Centrifugal forces (F)

→ It is given by $C.F = \frac{wv^2}{(12.7)R}$

w = LL in kN
v = Design speed in kmph
R = Radius of curve in m.

→ Horizontal load due to C.F is take to be act at 1.2 m above the level of carriageway.

7) Buoyancy force

→ For submerged bodies,
→ For large bridges underdeep bodies.
→ For low depth of submergence, it is neglected.

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8) Water pressure:

→ Horizontal force due to water current on submerged portion. It is given by,

$$P = \frac{wv^2}{2g}$$

P = pressure in kN/m²
w = unit wt of water
v = water current velocity (m/sec)
g = Acceleration due to gravity.

→ Force caused by water current are max^m at top of water level and zero at bottom ~~level~~ or bed level.

9) Thermal stress

→ Caused due to temperature change.
→ Stress develop at bearing and deck joints.
→ Stress are tensile so concrete fails and crack developed.
→ To avoid crack, additional steel reinforcement are provided perpendicular to main reinforcement.

JMP

10) Seismic forces

→ Considered when bridge are built in seismic or earthquake force.
→ wt of structure more, larger force exerted.
→ Should not be more than 12% of gravity force.

→ Horizontal Shear force (F_h) = $A_h \times W$

A_h = Design horizontal seismic coefficient.

$$= \left(\frac{Z}{2}\right) \times \left(\frac{I}{R}\right) \times \left(\frac{Sa}{g}\right)$$

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Z = zone factor,

= zone II, III, IV, V → 0.36

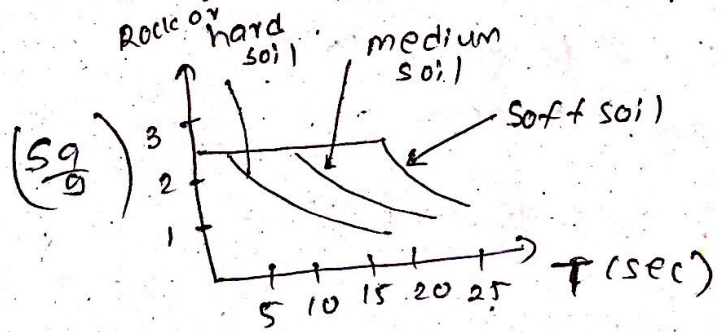
I = Importance factor

- Normal bridge: I = 1
- Important bridge: I = 1.2
- Special bridge: I = 1.5

R = Response reduction factor

- R = 3 for ductile detailing of pier
- R = 1 for bearing and expansion joint

$\frac{Sa}{g}$ = Design response spectrum value



ii) Earth pressure

→ Consider when bridge are surrounded by earth.

→ Centre of pressure lies at 0.42H

→ Colabomb. theory recommend 0.33H.

→ Minimum horizontal pressure is 4.8 kN/m^2

iii) Deformation stress-

→ Caused due to change in material property either externally or internally.

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→ It shouldn't be less than 16 % of DL and LL. (Stress)

✱ Lateral load distribution in bridge:-

A) Courbon's method (V Imp)

B) Distribution coefficient method.

A) Courbon's method

→ It is the distribution of deck slab load to longitudinal girder of T-beam bridge.

→ Considered as simple, powerful and highly popular method for longitudinal girder analysis.

Assumptions:-

i) Bridge deck slab $(\frac{L}{B}) = (2-4)$

ii) No. of cross beam interconnecting longitudinal girder = 5 (minm)

iii) Depth of cross-girder should be equal to 0.75 times the main (longitudinal) girder.

✱ Phenomenon of deck slab load distribution:-

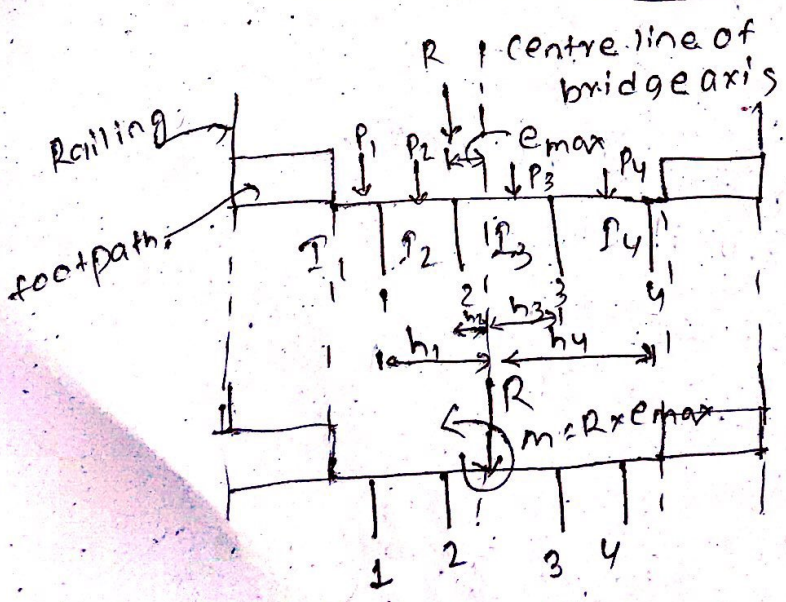

Fig:- load distribution of deck slab to longitudinal girder

stress)

Load by 1st girder

$$\Rightarrow \left[\frac{R \times I_1}{\Sigma I}\right] + \left[\frac{M \times h_1 \times I_1}{\Sigma (I \times h^2)}\right]$$

where $\Sigma I = I_1 + I_2 + I_3 + I_4$

$\Sigma (I \times h^2) = I_1 h_1^2 + I_2 h_2^2 + \ldots\ldots$

Load shared by 2nd girder

$$\Rightarrow \left[\frac{R \times I_2}{\Sigma I}\right] + \left[\frac{M \times h_2 \times I_2}{\Sigma (I \times h^2)}\right]$$

Load shared by 3rd girder

$$\Rightarrow \left[\frac{R \times I_3}{\Sigma I}\right] - \left[\frac{M \times h_3 \times I_3}{\Sigma (I \times h^2)}\right]$$

Load shared by 4th girder

$$\Rightarrow \left[\frac{R \times I_4}{\Sigma I}\right] - \left[\frac{M \times h_4 \times I_4}{\Sigma (I \times h^2)}\right]$$

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